

Comparison of Acoustic Spectrometry, Compression and Shear Force Measurements in Ripening Pear Fruit

Abstract

A study of the mechanical properties of four pear varieties demonstrated that indices of texture obtained by Acoustic Spectrometry, Compression and Shear analyses showed similar patterns of change on ripening. Furthermore, studies on gel model systems indicated that stiffness coefficients obtained from acoustic spectra were influenced by pectin concentration, soluble and insoluble solids. The pectin fraction isolated from two of these varieties showed a trend in dissolution comparable to texture measurements. The data indicate that acoustic spectrometry, like shear and compression analyses, can be a useful monitor of pear texture.

Résumé

Une étude des propriétés mécaniques de quatre variétés de poire indique que les indices de texture obtenus par spectrophotométrie acoustique, compression et point de déformation, montrent des tendances similaires de changement en fonction de la maturation. De plus des études sur des systèmes de gélification indiquent que les coefficients de solidité provenant du spectre acoustique sont influencés par la concentration en pectine et par les solides solubles et insolubles. La fraction pectine de deux variétés indique une tendance de solubilité comparable aux mesures de texture. Les résultats obtenus montrent que la spectrométrie acoustique tout comme la compression et le point de déformation peut être un moniteur utile de la texture de la poire.

Introduction

Instruments and techniques available to measure the texture of fruits include compression devices, shearing tools, extrusion cells and newer techniques such as acoustic vibration. The use of such methods to monitor the texture of fruits and vegetables has been reviewed (Finney, 1969). The texture of ripe pear fruit varies considerably with the variety. Bartlett fruit have a so-called "melting quality" which results when the cells of pulp tissue are readily separated on maceration. Oriental-stock hybrids of pear fruits often exhibit a crisp texture which is most extreme when fruit develop "Yuzuhada disorder". This physiological disorder occurs when European and Oriental stock fruit are crossed by pollination or grafting (Ranadive and Haard, 1971). Four pear selections, which had widely different texture when ripe, were examined by a compression, a shear and an acoustic vibration method. One of the varieties examined exhibited "Yuzuhada disorder" and another had a "melting texture". The patterns of textural change obtained by the three measurements were similar, although acoustic vibration did not provide values which could be related between varieties on an absolute basis. The extent of pectin dissolution was measured in two varieties which respectively exhibited

"melting" and "crisp" texture. In addition, the acoustic spectra of pectin gel model systems were examined to provide further understanding of how vibration measurements relate to texture.

Materials and Methods

Harvesting and Storage — Four pear varieties were harvested from experimental plots of the Rutgers orchard between July and September of 1968. The fruit studied and designated here as A-D were: A (experimental variety (E.V. 501971413), B (E.V. 5071041446), C (E.V. 500371029), D (E.V. 500371406). The fruit was removed from selected areas of each tree by hand. The orientation of the fruit with the exposure to the sun and the topology of the tree was noted. The harvested fruit was stored at -1°C for 30-60 days until removal for final ripening. Pears were ripened at 20°C and 86% relative humidity for 5-8 days.

Acoustic Analysis — Pear selections (A-D) were analyzed by the Acoustic Spectrometer (Nametre Company, Edison, New Jersey) on the first, third, fifth and if necessary, on the eighth day of final ripening. The number of analyses was determined by the time it took the pear to reach optimal ripeness (Ballauf pressure test of two pounds). Prior to analysis, the pears were weighed and the mass recorded. A procedure modified from that of Abbott *et al.* (1968) was used to obtain acoustic spectra. Intact pears were either freely suspended from a bar by a thread tied to their stem or were alternately placed on a doughnut shaped styrofoam support. The choice between the two procedures was determined by the size of the pear and will be discussed below. Three separate spectra were obtained for each fruit by rotating the pear 90° between the readings. Stiffness coefficients were calculated from the acoustic spectra, as described by Abbott *et al.* (1968).

When the reciprocal of the mass of fruit are plotted versus the squares of the frequencies of the lowest — flexural-frequency ($f_n = 2$) resonance peaks, the points fall approximately on a straight line passing through the origin of the plot. The slope of this line, $f_n^2 n = 2$ divided by $1/m$, or $f_n^2 n = 2m$ was shown to be a measure of apple stiffness and the elastic moduli. This procedure was used to determine stiffness coefficients of resonating pear fruit.

Shear Analysis — A $\frac{3}{8}$ in longitudinal slice was removed from each pear and discarded. A circular cutter with an inner diameter of $1\frac{3}{4}$ in was used to cut out a $\frac{1}{2}$ in thick plug from the exposed pulp (2.41 in² area); a sample of lesser diameter was sometimes

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necessary with small fruit.

The circular pear sections were placed in an L.E.E.-Kramer Shear Press Cell which was inserted into an Instron Universal Testing Machine with the aid of a specially designed chamber (Amen, 1969). The Instron was fitted with a 20-1000 pound compression cell, and the full scale load was set at either 100, 200 or 400 pounds, depending on the resistance of the fruit. The instrument automatically integrated the area under the resulting force curve and yielded the inch-pounds of work necessary to shear the sample.

Ballauf Pressure — Small areas of peel tissue were removed from each side of the pear and a pressure reading was obtained with a Ballauf pressure tester equipped with a 5/16 in. plunger.

Acoustic Analysis of Pectin Model Systems — An experiment was designed to analyze the acoustic spectra of model systems containing varying amounts of low methoxyl pectin, glass beads (60/80 mesh) and sucrose, to mimic respectively the change in pectin, scleroids and soluble solids of the fruit. The model systems studied included pectin (0.5, 1.0, 1.5 and 2.0%), sucrose (0 and 2.0%) and glass beads (0, 0.1%). The pH of all model systems was adjusted to 3.4 with citric acid and one part CaCl_2 was added per 20 parts pectin (w/w) to allow gel formation at 5°C. Gels were formed in a polyethylene film reservoir and analyzed on a doughnut shaped support (Amen, 1969).

Extraction of Pectic Substances — The pectic substances of varieties A and C were analyzed as follows: Pear fruit (500 g) was thinly sliced and placed in a 2000 ml beaker containing 1000 ml of distilled water. A mechanical stirring apparatus was used for the turnover of slurry. Concentrated HCl was added until the pH, initially about 4, was 1.8-2.0. Heat was then applied to attain a temperature of 90-95°C, which was held for 60 min. Water lost by evaporation during the heat treatment was replaced. The mixture was squeezed through a double layer of cheese cloth and the exudate filtered through a fritted glass funnel.

The filtrate was chilled to 4°C and mixed with an equal volume of cold 2-propanol. The precipitate, referred to here as Alcohol Insoluble Solids, (A.I.S.) was collected on a double layer of cheese cloth and dried by lyophilization. Pectic substances were isolated from the A.I.S. by precipitation with aluminum and copper salts (Pintauro, 1967). Total carbohydrates were determined by the phenol method (Dubois, 1956) and uronide sugars were estimated by a modified carbazole method (Bitter and Muir, 1962). Degree of esterification was determined by saponification and titration (Schultz, 1965). The pectic substances isolated by this method represented the high molecular weight (protopectin) fraction.

Results and Discussion

Acoustic Spectrometry — Larger fruit were supported by the styrofoam support and smaller pears were suspended from a string during analysis. The former method was easier to work with, however, the styrofoam support acted to dampen the oscillations of the smaller fruit. It was not necessary to correlate peak heights of the two methods since the frequency

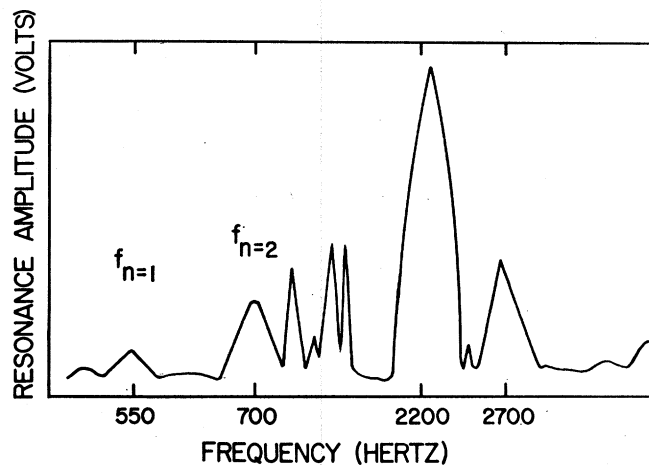


Fig. 1. Typical acoustic spectrogram of pear fruits, showing $f_n = 1$ and $f_n = 2$ peaks at 550 and 700 Hertz respectively.

of the peak, not the magnitude, was found to relate to textural parameters. Abbott *et al.* (1968) observed that the resonance peak of the second lowest frequency designated $f_n = 2$ was associated with flexural vibrations and was strongly influenced by apple size and firmness; the smaller and/or firmer the apple, the higher the frequency of the $f_n = 2$ mode. The marked differences in the degree of softening on final ripening of these pear varieties was useful in correlating spectra with apparent texture change on ripening.

A typical acoustic spectrum of postharvest pear fruit is shown in Fig. 1. The $f_n = 2$ peak of these varieties were identified in the range of 700-900 Hertz. The stiffness coefficients obtained from acoustic vibration of varieties A-D declined during final ripening (Fig. 2). The patterns of change in stiffness coefficient were identical to shear for varieties A-C and

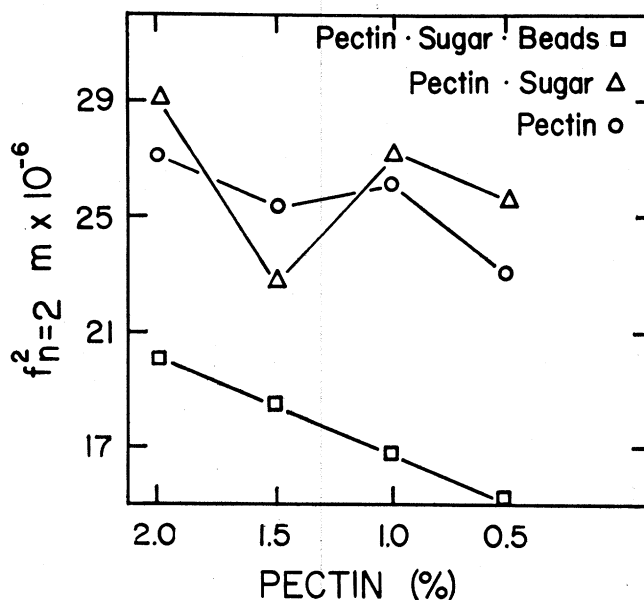


Fig. 2. Changes in stiffness coefficients with gels containing pectin (o); pectin and sucrose (Δ) and pectin, sucrose and glass beads (\square).

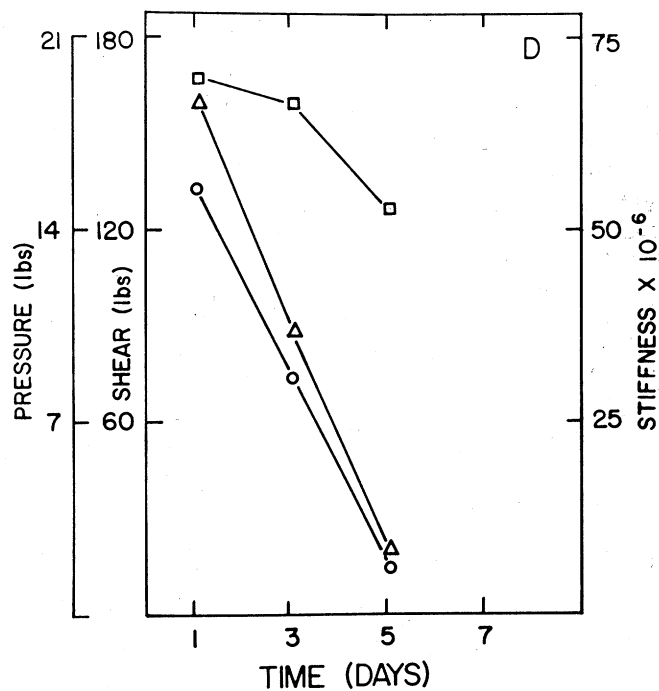
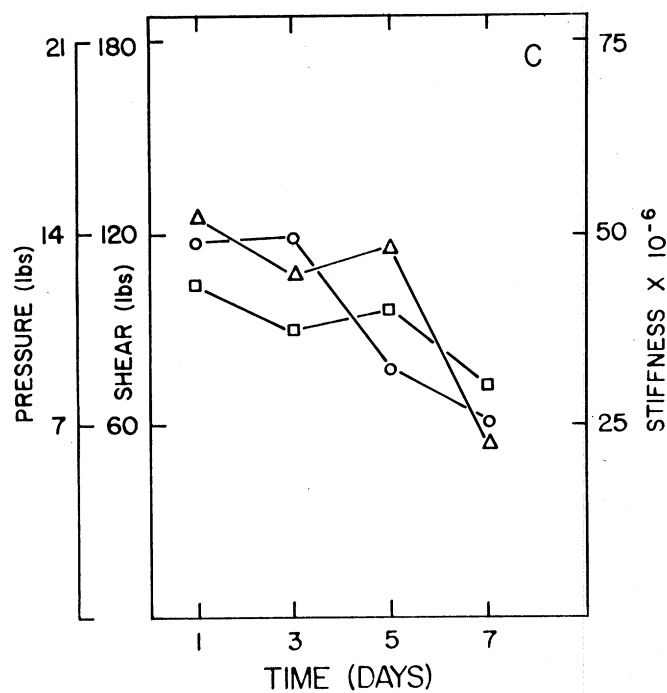
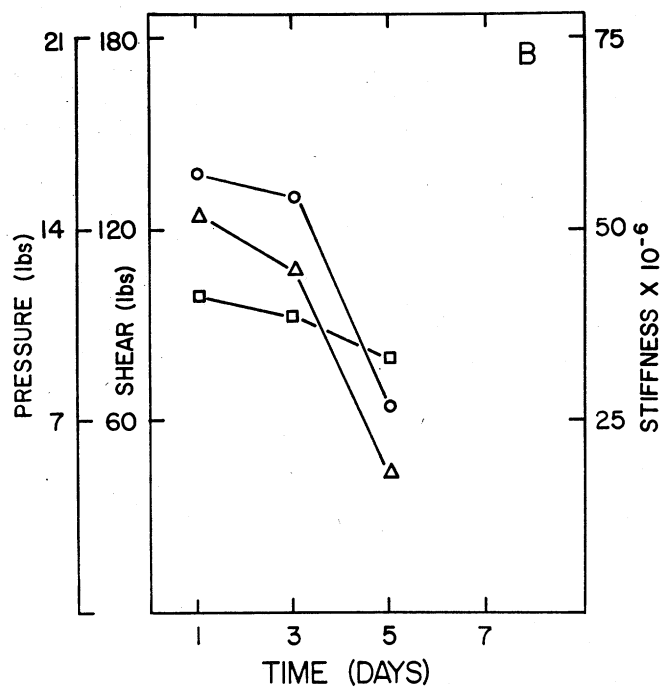
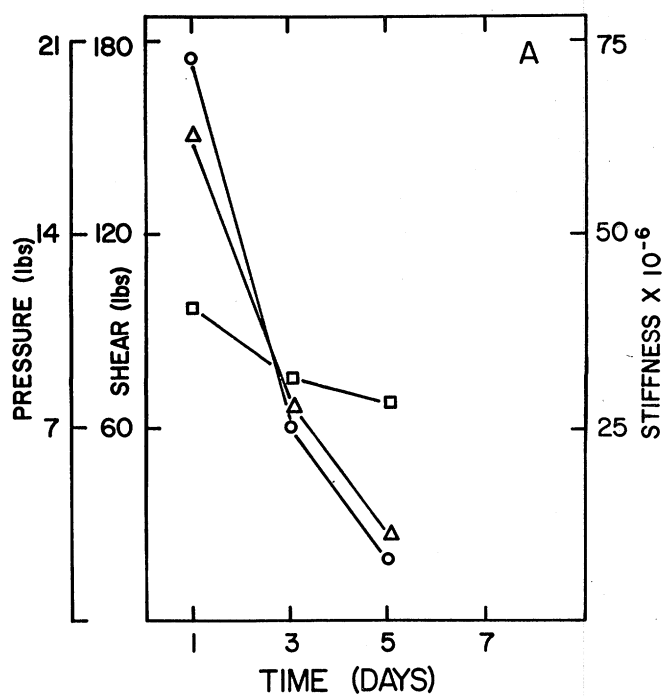


Fig. 3A-D. Comparison of the stiffness coefficient (\square), Instron shear (\triangle) and Instron compression (\circ) for varieties A-D during ripening.

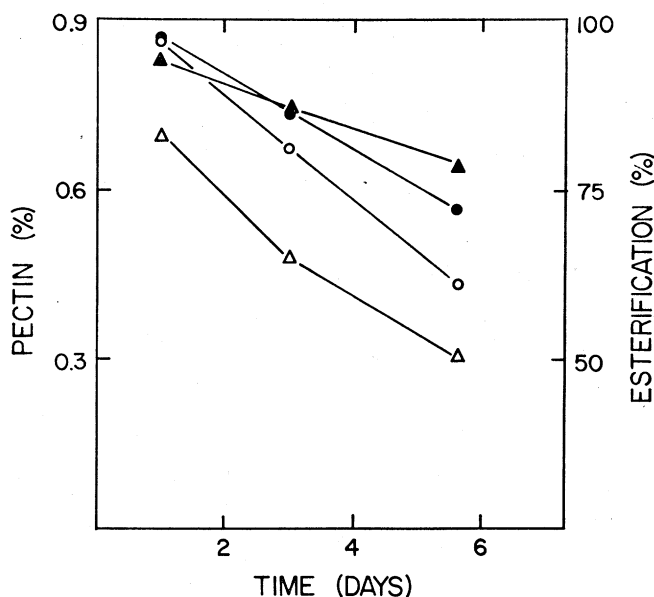


Fig. 4. Decrease in pectin (○) and degree of esterification of pectin (△) extracted from varieties A (○, △) and C (●, ▲).

was similar for variety D. The net change in stiffness coefficient during ripening related closely to the other indices of texture, although absolute values at any given stage of ripeness showed no consistent relation to compression and shear measurements (Table 1). The variation in stiffness coefficients obtained from different varieties may relate to fruit shape.

Instron Shear and Ballauf Pressure — The four varieties examined gave different initial and final measures of texture (Fig. 2). The work required to shear or compress the pulp appeared to be consistent with the organoleptic evaluation of texture. Variety D (Bartlett) had a melting quality texture on final ripening and readings of 2.2 lbs. and 16.1 in-lbs. for pressure and shear. Variety C ("Yuzuhada disorder") had a Ballauf pressure of 7.4 lbs. and a shear index of 56.5 in-lbs. after 8 days ripening. These values remained at this level for over 14 days until the tissue began to decay. The texture of variety C was similar to a raw potato.

Model System — Although the gels were less rigid in texture than the fruit, resonance was achieved and the $f_n = 1$ and $f_n = 2$ peaks were characterized at approximately 20 and 40 Hertz, respectively. The stiffness coefficients, calculated as described above, are represented in Fig. 3. Generally, the stiffness coefficient decreased as the percentage of pectin decreased (Fig. 3). The presence of sucrose in the system tended to increase the stiffness coefficient of the gel. Conversely, the presence of glass beads may have disturbed the gel matrix and generally reduced the stiffness coefficient of the gel.

A characteristic peak at 32 Hertz was identified as

Table 1* Net Change in Texture Index.

Variety	Ballauf Pressure (lbs.)	Shear (in-lbs.)	Stiffness Coefficient (X 10 ⁻⁶)
A	18.0	127.9	9.1
B	11.2	78.9	10.6
C	9.3	65.3	10.7
D	14.3	146.9	9.0

* Net change of Ballauf pressure, Instron shear, and stiffness coefficient with ripening of four pear varieties.

the one reflecting the presence of the glass beads. The possibility that a peak could exist which would reflect the presence of stone cells in fruit seems possible by this observation, although no such parameter appeared to relate to stone cell content of the pear varieties examined. The observation that firm gels had larger stiffness coefficients was consistent with the relation between this index and texture.

Analysis of Pectic Substance — The data in Fig. 4 show the results of pectin analyses of pear fruit A and C which were representative of pulp with melting and non-melting texture respectively. The yields of pectic substances (high molecular weight fraction) and the degree of esterification in variety A showed decreases typical of those observed in normal ripening fruit. Variety C, which exhibited "Yuzuhada disorder" and erratic indices of shear, compression and acoustic spectrometry on ripening showed less pectin dissolution. These data are consistent with the conclusion that acoustic, compression and shear analyses are indications of the melting quality of fruit which is, in turn, a function of pectin dissolution or intercellular cohesiveness.

Acknowledgements

This work was supported by U.S.D.A. Contract No. DA-12-14-100-8957. We acknowledge and thank the assistance of Drs. F. L. Hough and K. Bailey in providing pear fruit and the interest and valuable discussions of Dr. G. R. DiMarco.

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Received June 25, 1971.